

A DEFORMABLE SYSTEM COMPRISING A PART IN THE FORM OF A
RECTANGULAR BLOCK AND AN ACTUATOR

The present invention relates to a deformable system
comprising a part in the form of a rectangular block
5 coupled to an actuator enabling it to be deformed to
generate curvature in the long direction of the part.

Mirrors are already known for use around
synchrotrons in which varying curvature makes it possible
to change the focus of a beam of X-rays.

10 The present invention relates to a system enabling
such a part to be deformed, and is based on the idea of
using the part, e.g. a mirror, as a supporting structure.
To this end, instead of being in the form of a
rectangular parallelepiped, the part is more complex in
15 shape since it has projections at its ends enabling
deforming forces to be transmitted to the part.

The invention thus provides a deformable system
comprising a part generally in the shape of a rectangular
block, such as a beam, coupled to an actuator enabling
20 the part to be deformed by generating curvature in its
long direction, the system being characterized in that
said part, in particular a mirror, presents a main
portion to be deformed, the main portion carrying
projections at its ends such that, in longitudinal
25 section, the part presents an elongate U-shape, and in
that the actuator presents levers each presenting at
least one bearing point for acting on said projections in
order to transmit a force thereto in such a manner as to
deform the part.

30 The device may be characterized in that each lever
presents at least one bearing point constituted by at
least one rigid plane part, said plane part co-operating
with at least one ball for transmitting the force that is
to be applied.

35 At least one said ball may be centered by spring
blades distributed around its periphery.

The device may be characterized in that at least one lever presents a first bearing point disposed in an outside portion of the part, advantageously in line with the central portion and preferably adjacent to the face of the main portion that is opposite from said projections, and a second bearing point spaced apart from the first bearing point towards a free end of said projection and disposed on an inside portion of said projection.

The first and/or second bearing point may comprise two of said rigid plane parts. In which case, the first and/or second bearing point may comprise a rocker covering said two rigid plane parts.

Other characteristics and advantages of the invention appear on reading the following description given reference to the accompanying drawings, in which:

- Figure 1 shows the basic principle of the invention;

- Figure 2 is a side view of a device of the invention;

- Figures 3a and 3b are views from beneath and partially in section on AA and BB showing respectively the configuration of an inside bearing point and of an outside bearing point;

- Figures 4a and 4b are views on a larger scale showing the longitudinal ends of the Figure 2 device, Figure 4c is a view on a larger scale showing the central portion of Figure 2, and Figure 4d is an end view of Figure 2;

- Figure 5 shows a preferred embodiment of a ball-centering device; and

- Figures 6, 7a, 7b, and 8 show various embodiments of the invention.

The part P to be deformed and shown in Figure 1 presents a central portion 10 in the shape of a rectangular block to be deformed extending between two main and generally plane surfaces 16 and 17 with two

extensions 11 and 12 at its ends, these extensions 11 and 12 preferably extending perpendicularly to the plane of the central portion 10. The projections 11 and 12 give the part an elongate U-shape when seen in section. These
5 projections are relatively solid so that they deform only negligibly when a force is applied thereto in order to deform the central region 10.

The part P, in particular a mirror, is preferably machined from a single block of material, e.g. of Si,
10 SiO₂, SiC, Zerodur (trademark in the name of Schott), ULE (trademark in the name of Corning), or any other material of glass or crystal type.

The part P is deformed by levers acting on the projections 11 and 12 via bearing points A1 and B1 for
15 the projection 11 and bearing points A2 and B2 for the projection 12 (Figure 1). The bearing points A1 and A2 are positioned in the inside portions 11' and 12' of the projections 11 and 12, preferably in the immediate vicinity of their free ends 13 and 14. The bearing
20 points B1 and B2 are disposed on the outside of the part P, advantageously in line with the central portion 10, and preferably as close as possible to the face 15 to the part P that is opposite from the projections 11 and 12.

In order to curve the main portion 10 of the part P,
25 moment type forces are transmitted to the two ends of the part. To this end, it is appropriate to fix a lever to each end. An actuator 20 such as a hydraulic cylinder (Figure 2) presenting a cylinder 25 and a rod 26 serves to exert thrust on the levers.

30 The assembly described below allows two levers to be associated with the part P. One of the features of this configuration is that, given that the rectangular block 10 is made of a material that is generally brittle when it constitutes the mirror, it enables large forces to be
35 transmitted thereto by achieving good control over pressures at the points where said forces are applied,

and does so without requiring very high precision machining.

In addition, the movements induced by temperature variations can take place without slip and without any increase in force (which is important when it is not possible to grease a mechanism due to the conditions under which it works) because of the following:

- a) the bearing points on the rectangular block are constituted by plane pellets 1 of hard metal which receive the force via balls 5 pressing against the centers of the pellets 1, which pellets then serve to distribute the pressure delivered by the balls; and
- b) cylindrical spring blades 7 distributed around the balls keep the balls 5 centered on the plane pellets 1 while allowing small displacements parallel to the bearing plane.

Mounting fixed bearing points via spring blades 7 enables them to rock while maintaining a uniform bearing force so as to transmit the pressures and forces from the actuator 20 and distribute them over the bearing zones.

It is preferable to use a pair of ball systems 1, 5 for each bearing point A1, A2, B1, and B2. This disposition is shown in the section views of Figures 3a and 3b.

In addition, for the inside bearing points A1 and A2 (see Figure 3a), it is advantageous to use an additional part 6 which covers the two balls 5 via housings 7 and 7' and which presents a region 8 of spherical outline enabling it to rock in co-operation with a plane face 32 of the lever 30. This additional rocking movement 6 operating like a rocker bar serves to distribute pressure uniformly between the two bearing points provided by the two balls 5, and thus to obtain deformation that is well-distributed over the width of the main region 10 that is to be curved. It will be understood that the other bearing points B1 and B2 do not produce any deformation of the extensions 11 and 12, but serve above all to act

as reference points for the lever, e.g. at the ends of the region 10 (in particular level with the neutral fiber of said region), and can therefore be implemented without a rocking connection 6.

5 Lateral movement of the part 10 relative to the levers 30 and 40 is prevented by two parts 4 extending from the lever 30 parallel to the longitudinal direction of the part P and bearing simply against the side edges of the region 10 (see Figures 3b and 4a).

10 Each of the levers 30 and 40 comprises a main arm (31, 41) running along a plane longitudinal end of the part 4 and carrying the outside bearing points B1 and B2, and a plate (41, 42) carrying the inside bearing points A1 and A2.

15 The levers are held pressed against the part 10 firstly by the spring 2 secured to the plate 41 which holds the lever 40 pressed against the parts 1 (Figure 3a) and by the spring 3 secured to the plate 42 of the lever 40 and which holds it pressed via an end tab 20 45 (and/or 35) of the arm 41 (and/or 31).

The actuator 20 which is embedded at 21 and 22 between the two levers 30 and 40 acts to urge the two levers 30 and 40 apart, and it can be seen that the assembly is properly referenced in three dimensions.

25 In order to minimize deformation of the part P when it is desired to support the assembly constituted by the part P, the actuator 20, and the levers 30 and 40, an isostatic interface is used that is situated in the plane of the neutral fiber FNE of the central region 10 of the part P.

30 This is represented in the drawings by three bearing points 50:

- two on one of the levers (e.g. 40, see Figure 4d);
- and
- 35 • one on the other lever (e.g. 30, see Figure 4a).

The device shown in the drawings enables the assembly to be supported in a position in which the

extensions 11 and 12 are directed upwards, but this is merely an example and the design is equally applicable to extensions 11 and 12 that extend downwards.

The contacts implemented by the bearing points (or the corresponding center bearing point which is the center of the sphere when using a spherical bead 50) are situated in the plane of the neutral fiber FNE of the main portion 10 of the part P, the neutral fiber FNE passing through the middle of the region 10.

In the preferred situation, two balls 50 are thus placed on side arms 52 of one of the levers (e.g. 40, Figure 4d). A hole 51 serving to interface with the other ball 50 is formed on the other lever (e.g. 30, Figure 4a).

The positions of the centers 0 of these balls 50 along the length of the region 10 advantageously pass via a plane ZZ' perpendicular to the long direction and passing via the points 21 and 22 where the actuator 20 bears against the levers 30 and 40, thus making it possible to ensure that the mass of the actuator does not introduce any moment in the levers 30 and 40, and thus does not introduce any variation in curvature.

In order to limit deformation due to gravity, compensation via bearing points (or retaining means depending on the orientation of the part) can be secured between the actuator 20 and the part P, and they are adjusted to minimize the sag of the part due to gravity. An example application consists in using springs to perform this function, as shown in Figures 2 and 4c where there can be seen compensators 27, 28, and 29 between the central portion 10 of the part P and the cylinder 25 or the rod 26 of the actuator 20, together with compensation springs 27', 28', and 29'.

In a variant (Figure 6), the thickness of the region 10 may vary with a relationship that makes it possible, when moments are applied, to obtain a shape other than a shape having a cylindrical profile that is symmetrical

about the middle of the length of the mirror: e.g. shape that is elliptical, parabolic, or polynomial in section without any axis of symmetry.

5 In another variant of the invention (Figures 7a and 7b), the above effect is obtained by modifying the width of the part (Figure 7a) along its length (a curvilinear rectangular block), using a relationship of the linear type or possessing polynomial terms of higher order. Under such circumstances, symmetry is conserved for the
10 two lateral profiles 10_1 and 10_2 relative to the length of the mirror.

In another variant of the invention, the above effect is obtained by changing the lengths of the levers 30 and 40 (Figure 8).

15 Any combination of these variants is also possible.